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# Technical Notes ON BRICK & TILE CONSTRUCTION

STRUCTURAL CLAY PRODUCTS INSTITUTE

A. I. A. FILE NO. 5-F

## REINFORCED BRICK MASONRY - II

**(Properties of Reinforced Brick Masonry)**

### INTRODUCTION

As with other construction types, the properties of RBM, particularly those which determine structural performance and durability, depend upon: (1) the quality of materials; (2) the workmanship; (3) the design.

During the past 30 years research has been conducted on RBM for the purpose of establishing rational bases for design, to determine and evaluate the factors affecting the strength of RBM structures and to determine ultimate strengths of reinforced brick masonry members which may be used as bases for working stresses. RBM is considered to be a homogeneous construction, produced by combining such materials as brick, mortar and grout, and steel reinforcement. Therefore, it will be found that the performance of any one of the component materials is affected not only by the properties of that particular material, but often to an equal degree by the properties of the other materials with which it is combined. Therefore, in discussing the properties of RBM, it is important that the properties of its component materials first be considered.

### MATERIALS OF CONSTRUCTION

Reinforced brick masonry is essentially the combining of brick and reinforcing steel with mortar and grout as the bonding agents to produce a homogeneous construction able to sustain flexure, compression, shear and tension stresses in a manner similar to that of reinforced concrete.

***Brick.*** Of the materials used in RBM construction, the physical properties of the brick produced in different localities probably vary more than the properties of either the mortar or grout or the reinforcement. This is due to the fact that the properties of the clays and shales used in their manufacture vary greatly from one deposit to another. For economic reasons it is impractical to treat the clays so as to produce uniform raw materials. The resultant product, therefore, will reflect the variations of the natural clays and, to a much greater extent than most other manufactured articles, may be said to be a natural product.

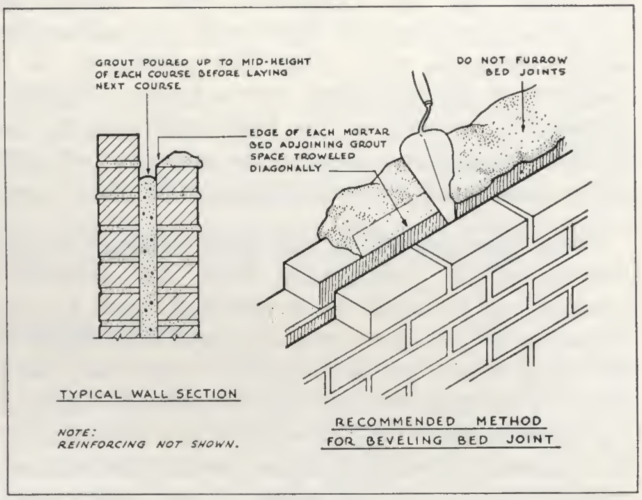


Fig. 1

The properties of brick which have the most important effect upon the design, performance and durability of RBM are size, compressive strength, water absorption (including saturation coefficient) and those properties affecting bond between brick and mortar, such as suction (rate of absorption) when laid and surface texture.

**Size.** The sizes of brick used in RBM help determine the thickness of wall, since the mortar joint thicknesses are determined by the diameter of reinforcing steel and the necessary clearance between steel and brick. In Table 1 are listed the sizes of

**TABLE 1**
**NOMINAL MODULAR SIZE OF BRICK ①**

| Thickness, in. | Face Dimension in Wall | |
|---|---|---|
| | Height, in. | Length, in. |
| 4 | 2 | 12 |
| 4 | 2⅔ | 8 |
| 4 | 2⅔ | 12 |
| 4 | 4 | 8 |
| 4 | 4 | 12 |
| 4 | 5⅓ | 8 |
| 4 | 5⅓ | 12 |

① Nominal sizes include the thickness of the standard mortar joint for all dimensions.

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modular brick currently available. Few manufacturers produce all of the sizes listed and it is recommended that the engineer or architect ascertain the units available in any locality before proceeding with the design. The dimensions shown are nominal dimensions which are joint center-line dimensions and differ from the specified unit dimension by the thickness of the mortar joint with which the unit is designed to be laid.

**Compressive strength.** The compressive strength of brick has an important effect upon the compressive strength of RBM and, in combination with absorption and saturation coefficient, is a measure of the durability of the brick. Approximately 75 per cent of the brick produced in the United States have compressive strengths of 4500 psi or over, while 40 per cent have 8000 psi or over.

When the strength of the solid masonry is not determined by preliminary tests, the allowable stresses may be based on an assumed value $f'_m$ not exceeding 60 per cent of the compressive strength of the brick when Type A-1 mortar is used (see Vol. 4 No. 6, Technical Notes). Such an assumed value of $f'_m$, however, shall not exceed 2000 psi. Consequently, if masonry strength is determined in this manner, any brick having a compressive strength of at least 3334 psi will provide the maximum possible working stresses for an RBM design.

A more realistic and economic method of determining working stresses is on the basis of $f'_m$ established by preliminary tests on brick prisms built of similar materials under the same conditions and, insofar as possible, with the same bonding arrangement as for the structure. Any additional masonry strength resulting from the use of higher strength brick can, therefore, be used in establishing higher working stresses and will result in a more economical design.

**Water absorption.** The water absorption and saturation coefficient (ratio of cold water absorption to boiling water absorption or C/B ratio) of brick, along with compressive strength, are measures of resistance to freezing and thawing. ASTM Specifications C62- and C216-, for Building Brick and Facing Brick respectively, prescribe limits on absorption and saturation coefficient, together with compressive strength. The explanatory note appended to Specifications C62- includes a discussion of the grading of brick based on durability or resistance to freezing and thawing.

**Suction.** The pores or small openings in burned clay products function as capillaries which tend to draw water into the unit. This action in a brick is called "rate of absorption" or "suction". Numerous tests of the tensile strength of bond between mortars and brick indicate that suction has a most important effect upon the tensile bond strength upon which transverse strength and watertightness of brick walls largely depend. These test data indicate that maximum tensile bond strength between mortar and brick is developed when the suction of the brick *at the time of laying* does not exceed 20 grams (0.7 oz.).

Suction of brick produced commercially vary from 1 to 2 grams to 60 or more grams, as determined according to the procedure outlined in ASTM Standard Methods of Sampling and Testing Brick, C67-. However, suction of units may be reduced to any desired value, prior to laying, by wetting.

**Surface Texture.** The texture of the brick surface in contact with the mortar also has an important effect upon the tensile strength of the bond between brick and mortar. Data are available which indicate that tensile bond strength between mortar and smooth brick surfaces averages about 25 per cent less than between mortar and roughened surfaces. By smooth surface is meant surface not altered or marked in manufacture but left as formed by the die or mold. Roughened surfaces are those on which the "die skin" has been broken by mechanical means such as wire cutting, brushing or scratching.

***Mortar and Grout.*** Perhaps the most important property of mortar affecting the performance of RBM is its ability to form a strong and durable bond with the brick and reinforcing steel. Other important properties are workability, compressive and tensile strength, durability and volume change under varying conditions to which it may be subjected. Of the cement-lime mortars in common use, none will rate highest in *all* of these properties. In selecting a mortar it is necessary, therefore, to evaluate the properties of various mortars with a view of its use requirements.

ASTM Tentative Specifications for Mortar for Unit Masonry, C270-, include 5 types of mortar. Portland cement-lime mortars meeting ASTM requirements for types A-1 and A-2 are recommended for reinforced brick masonry.

**Workability.** Workability is affected by properties of the ingredients, particularly the lime. Mortars containing highly plastic limes and well graded sand have better workability. Admixtures are available which improve mortar workability; however, they should be used with caution in RBM unless their

effect on bond between mortar and brick and mortar and steel is known.

Water retentivity of mortar, which is in effect a measure of its workability, increases with increased proportions of lime; however, the properties of the lime have an equal or greater effect than proportion. Highly plastic lime putties produce mortars of high water retentivity.

**Strength.** Strength of mortar, both compressive and tensile, increases with increased proportions of cement and with decreased water-cement ratio. High strength mortars have higher bond strength between mortar and reinforcement than low strength mortars. However, there does not appear to be consistent relationship between mortar strength and strength of bond between mortar and brick. For example, Type A-2 mortar, on the basis of many laboratory and field tests, develops greater tensile bond strength between brick and mortar than does Type A-1, a higher strength mortar. Mortar affects the compressive strength of masonry walls approximately proportional to the cube root of its strength.

**Bond—Mortar to Brick.** All other things being equal, tensile bond strength between mortar and brick increases with increased flow of mortar. Therefore, the mortar should be mixed with the maximum amount of water consistent with workability. Of equal importance is the suction of the brick when laid. Tensile bond strength decreases rapidly as brick suction increases above 20 grams (0.7 oz.).

**Bond—Mortar to Reinforcement.** Bond strengths of from 500 to 1000 psi can be obtained with A-1 and A-2 mortars and the reinforcing steel.

**Durability.** Types A-1 and A-2 mortars recommended for use in RBM have high resistance to freezing and thawing. Reinforced grouted brick masonry resists the excessive penetration of moisture, so durability of the mortar is not a problem.

**Volume Change.** Thermal volume change should be given consideration in the design of structures (see Vol. 3 No. 9, Technical Notes). Mortars containing reactive chemical compounds, such as unhydrated magnesium oxide, may expand sufficiently in the presence of moisture to cause disintegration of the masonry and their use should be avoided.

**Admixtures.** Admixtures are, as a rule, added to mortars to produce water repellency, to improve workability or to increase water retentivity. Certain admixtures, however, have a deleterious effect upon bond between mortar and both brick and reinforcing steel. They should not be used in mortars for RBM unless laboratory data or performance records are available which will indicate that such mortar will develop satisfactory bond.

***Reinforcement.*** Steel deformed bars meeting the requirements of ASTM Tentative Specifications A305- are recommended for use in principal RBM members. Bond stresses developed by bars meeting these requirements are from 50 to 100 per cent greater than with plain or old type deformed bars.

While few data are available at this time (1954) on bond developed by ASTM A305- bars in brick masonry, it seems reasonable to assume that the bond will be substantially increased over that obtained with the old type bars and that allowable bond stresses may be increased accordingly.

## WORKMANSHIP

The quality of workmanship is another factor having a most important effect upon the performance and durability of reinforced grouted brick masonry. As in conventional unreinforced construction, all brick should be laid with *full* head and bed joints. The ends of the brick should be buttered with enough mortar to fill the head joint and the bed joints *should not be furrowed.* After the bed joint mortar has been spread on the wall, it should be sloped towards the center with the trowel, as illustrated in Fig. 1, to minimize the amount of mortar forced into the grout space when the brick are shoved into place. Any mortar protruding into the grout space should be cut off before the grout is poured.

The grout is poured one course at a time to midheight of each course as shown in Fig. 1. One of the outer wythes or tiers may be built up ahead of the other not more than three courses before grouting. Each pour of grout should be carefully puddled with a wooden puddler.

In RBM more than 2 brick in thickness, the inner wythes of brick may be placed or "floated" in the grout with not less than ½ in. of grout between brick. Wherever possible, pour the grout from the inside face of the masonry, taking extreme care to prevent any of it from staining the face of the masonry to be left exposed.

With the exception of the grouting techniques described above, the workmanship necessary to obtain best results in RBM work differs little from

that recommended for conventional masonry construction. It is necessary, of course, that the reinforcing steel be placed accurately as called for on the plans and that the proper clearances between steel and masonry be maintained as set forth in the specifications.

*Attention should be called to the fact that, in reinforced grouted brick masonry, no masonry headers are employed.* If a pattern bond other than simple running bond is desired, "clipped" headers may be used in the face of the wall.

**DESIGN**

Design of RBM, as it affects performance and durability, will be discussed in more detail in a subsequent issue of Technical Notes. The basic theory of structural design is identical to that for reinforced concrete. The actual RBM details used for any structure must be based upon the particular design conditions and the sizes and types of materials available. The designer must use ingenuity and keep in mind the basic factor of tying all parts of the structure together.

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